

# **Integration of Geomorphology and Geostatistical Uncertainty Analysis into Remedial Alternatives Selection based on Hill-topping and SWAC**

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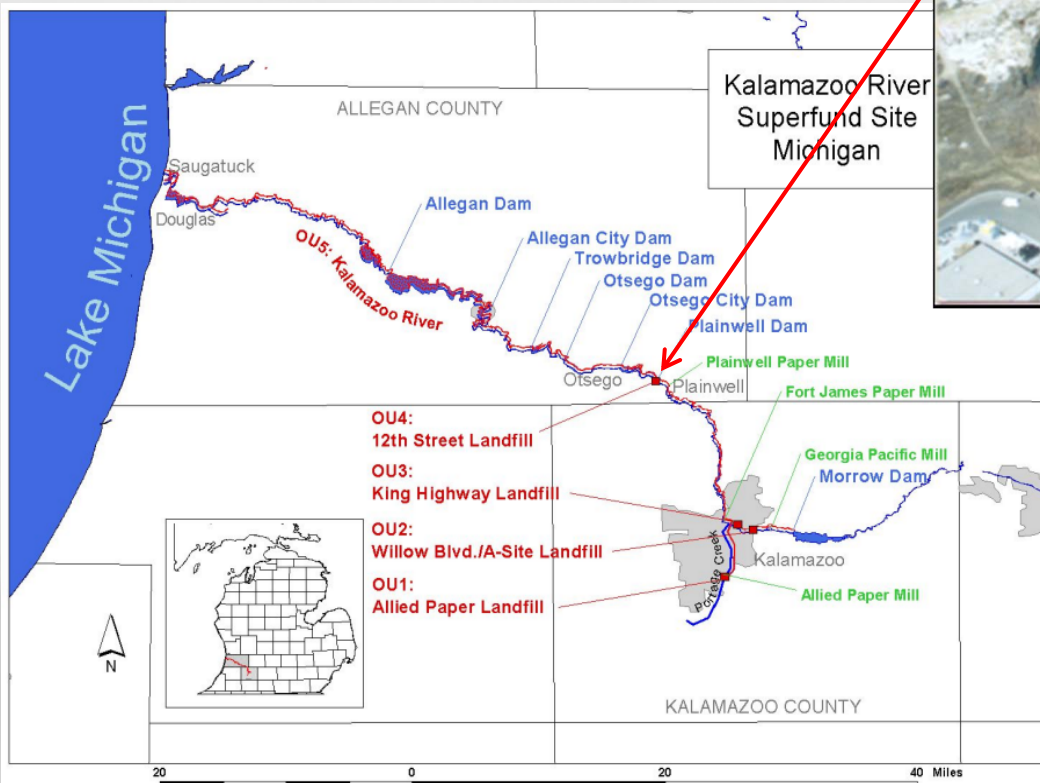
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**Seventh International Conference on  
Remediation of Contaminated Sediments  
February 4-7, 2013**

# Allied Paper Inc./Portage Creek/Kalamazoo River Superfund Site Former Plainwell Impoundment Overview

- Southeastern Michigan
- Approximately 64 Acres Formerly Impounded Sediments



- 280,000 cy soil/sediment
- 2,600 kg PCBs
- Recycled paper waste

# Assess Exposures to Receptors With “Small” One to Two Acre Home Ranges



# Exposure Estimation Approach

## (Moving Home Range)

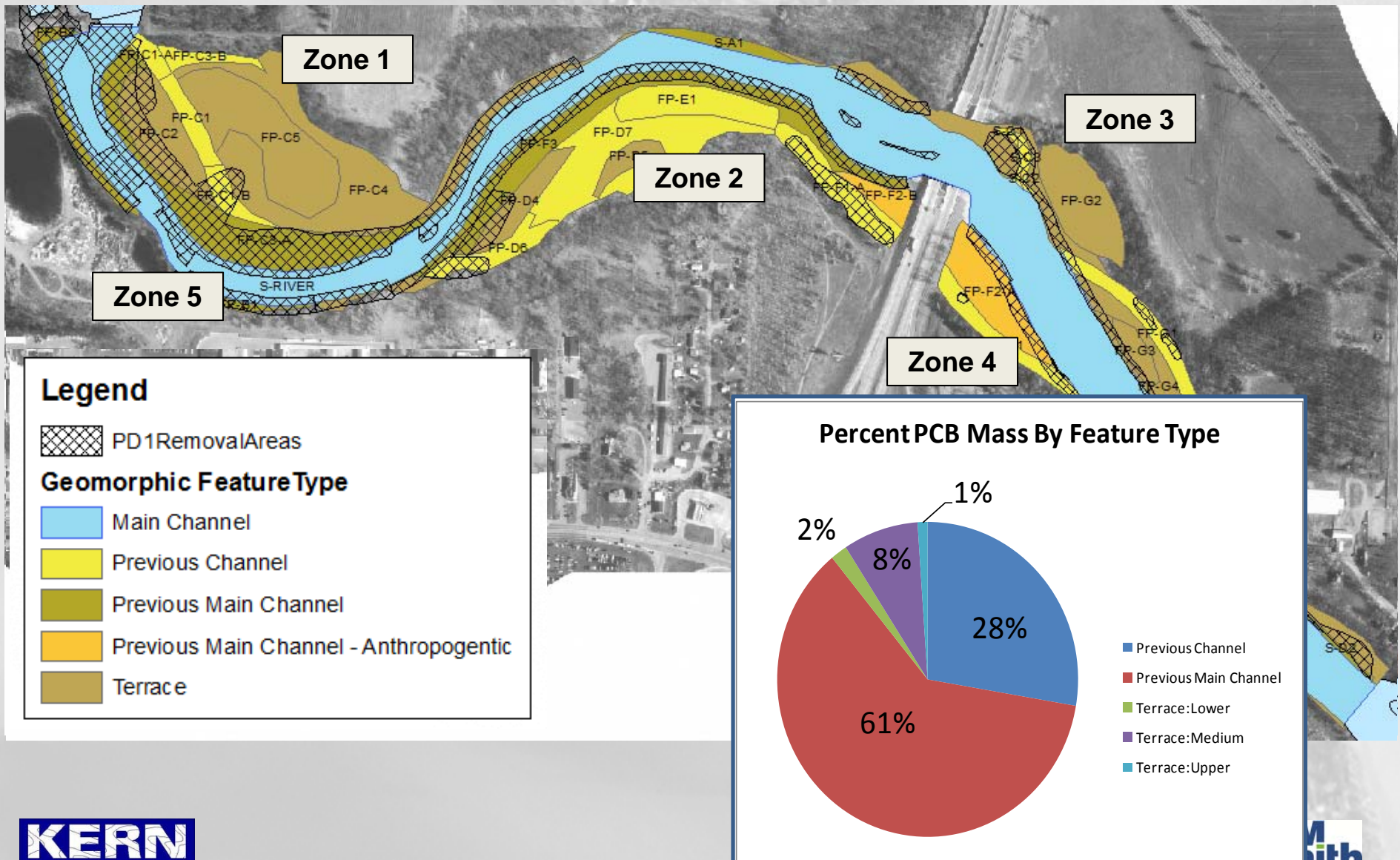
- Integrate analytical and geomorphic data.
- Estimate exposure “surface” throughout site.
  - Stochastic interpolation on a 5 foot regular grid.
- Average grid values in each “potential” home range.
- Calculate performance metric(s)
  - Small Scale: Percentage of home ranges with SWAC exceeding risk based threshold(s).
  - Intermediate Scale: SWAC within defined subareas
- Vary action limits and compare performance.
- Quantify and communicate uncertainty.

# Geomorphic Information

## Aerial Photo Analysis



# Geomorphic Features Derived From Aerial Photography



# Identification of Model for Surface PCB

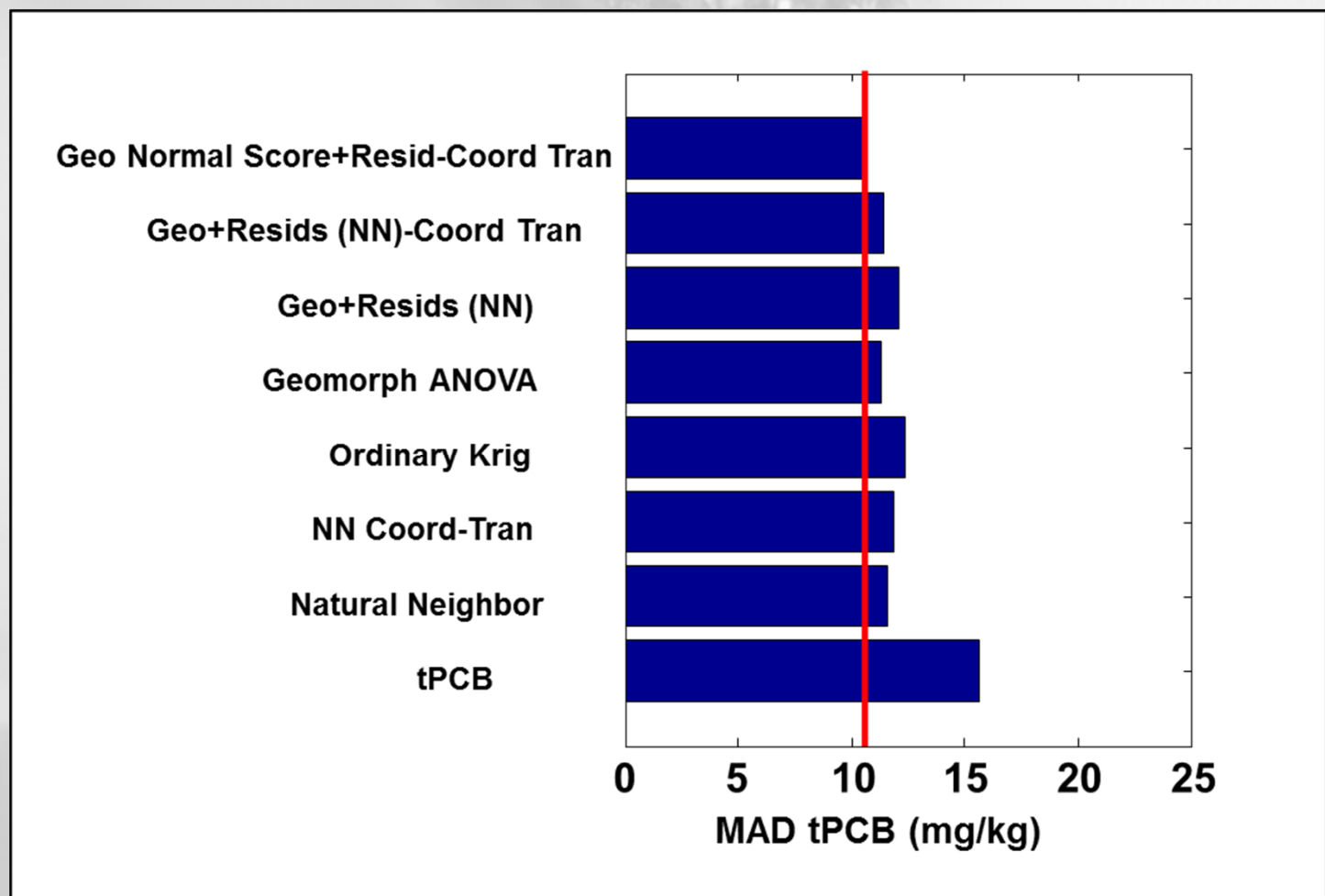
Integrating Analytical and Geomorphic Information

$$PCB = \mu_{grand} + \mu_{Main\ Channel} + \mu_{Channel} + \mu_{Terrace} + R(x, y)$$

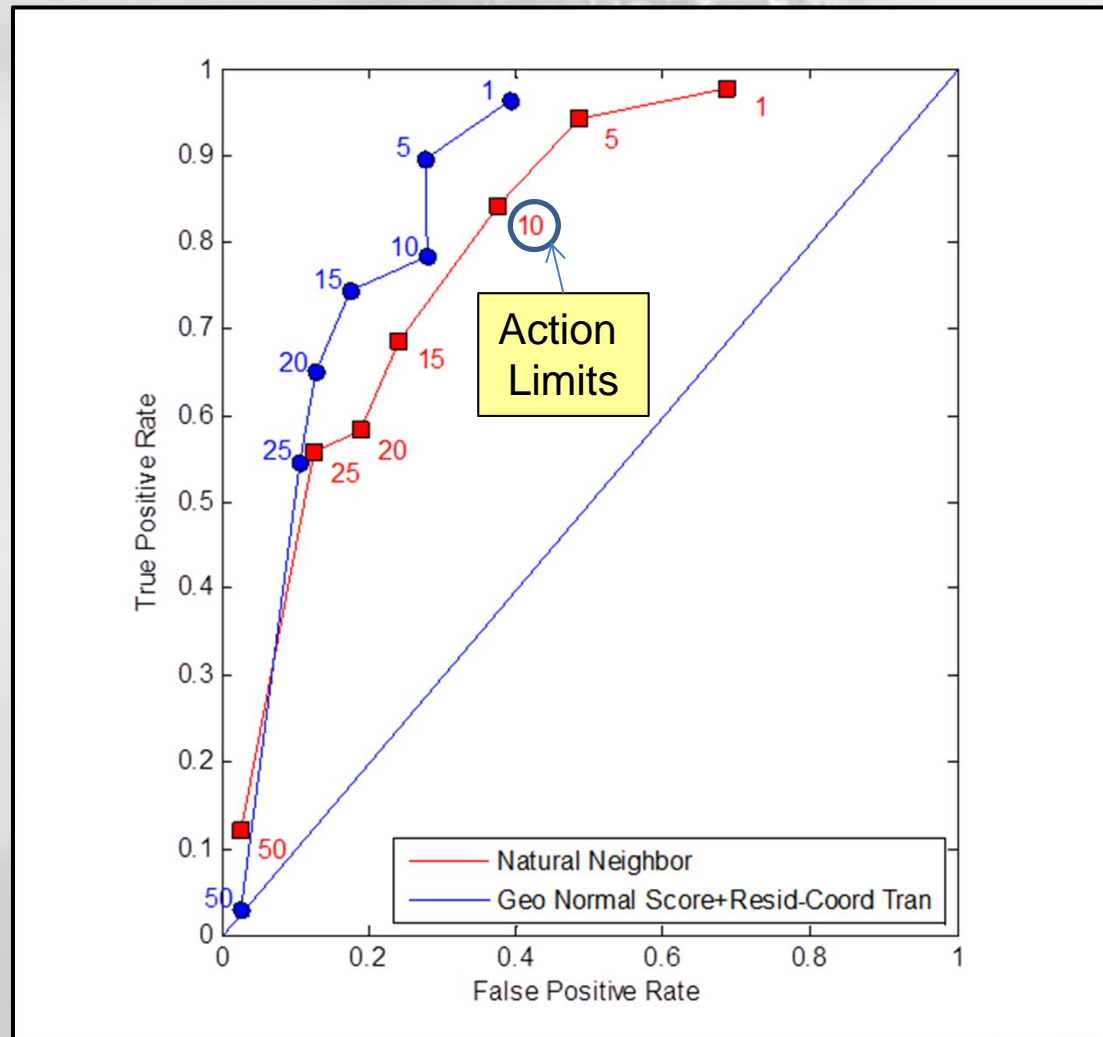
- **Competing Approaches**
  - Ignoring Feature Types
    - Prediction from the grand mean
    - Direct Interpolation of analytical data
  - Incorporation of geomorphic features
    - Integrating spatial structure in  $R(x, y)$
    - Direct interpolation of  $R(x, y)$
    - Indicator kriging of  $R(x, y)$
  - *Geometric and river coordinates systems compared for all methods*

# Cross Validation Study

## Mean Absolute Error (mg/kg)

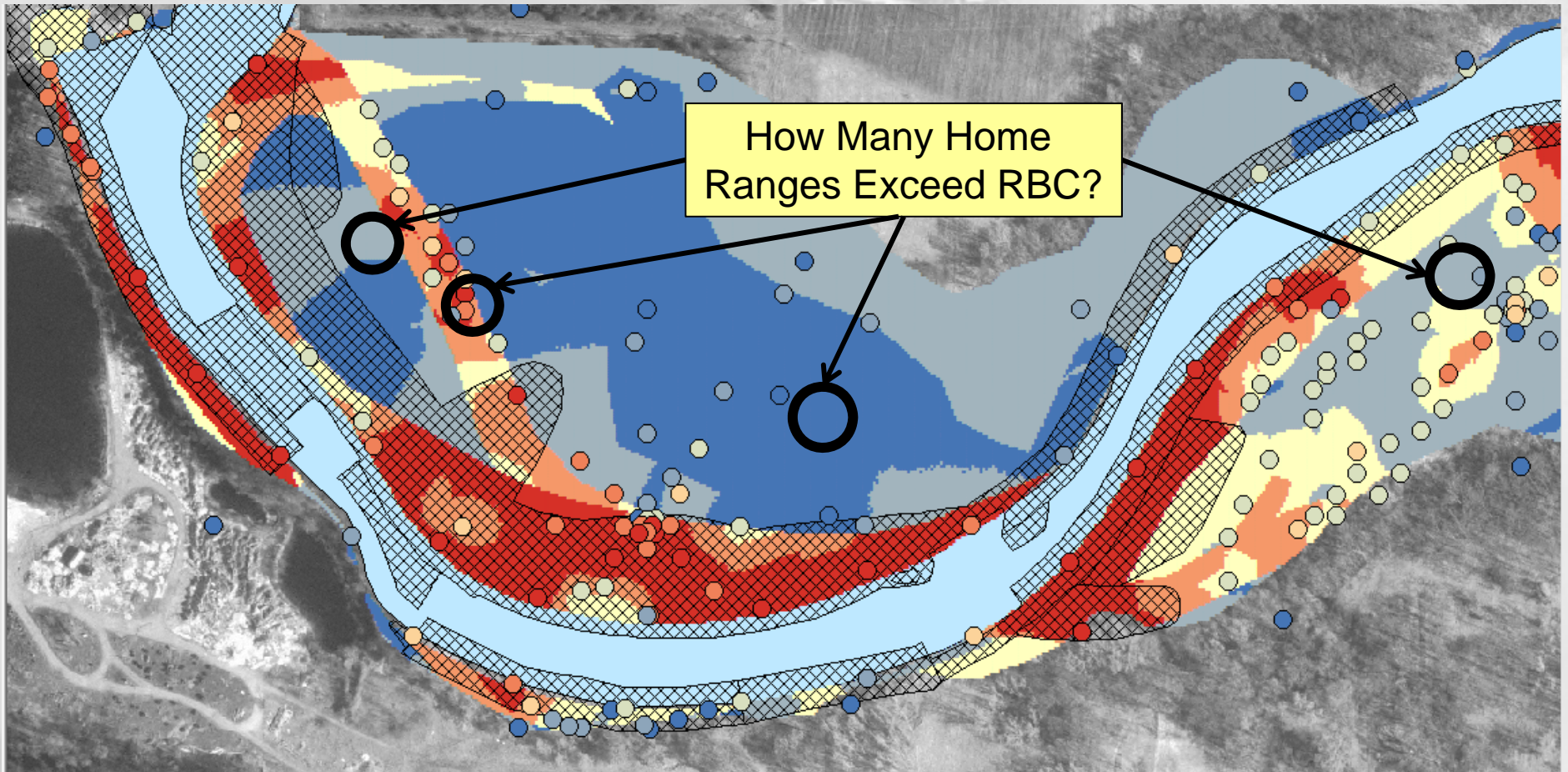


# Receiver Operating Characteristic Curve (True Positive vs. False Positive)



# Data to Model Comparison

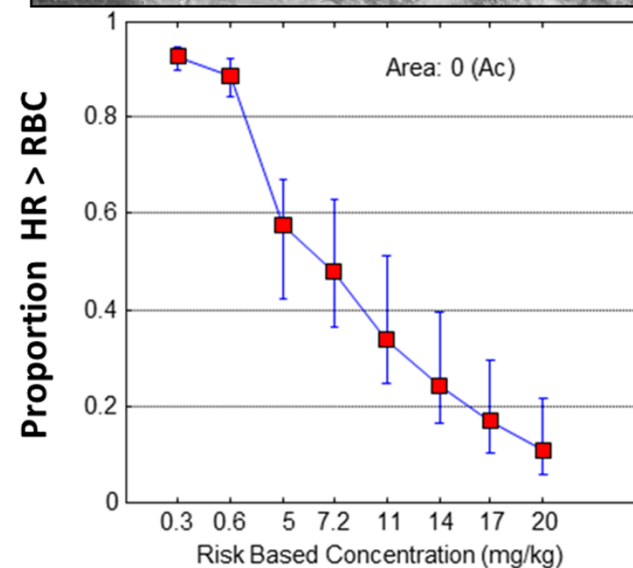
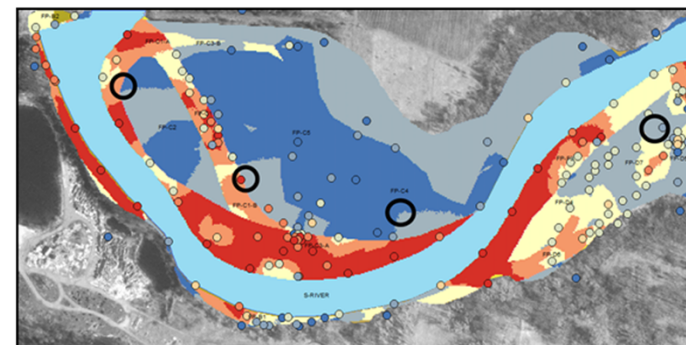
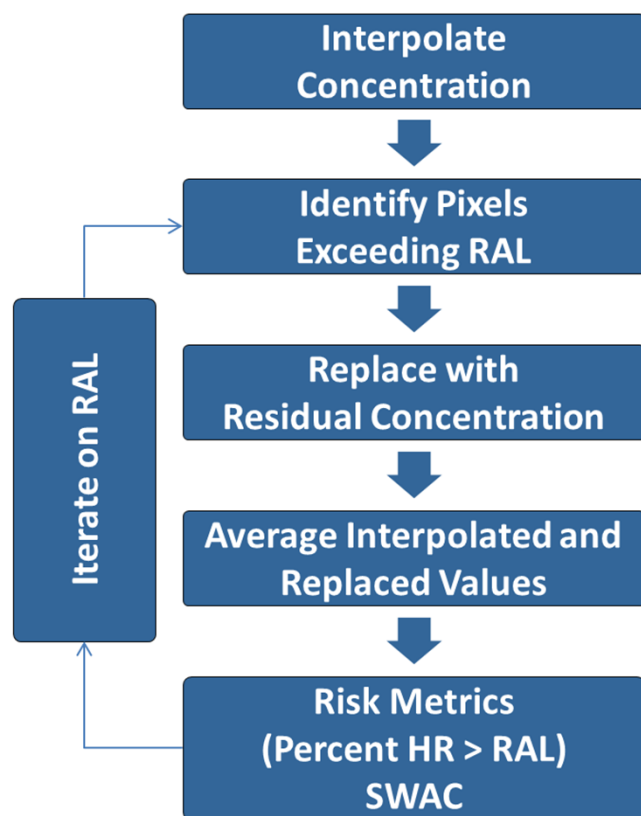
*(Best Estimate of Exposure)*



# Exposure Estimation and “Hill-topping”

*(Apply the Concentration Model for Decision Making)*

## Hill-topping Algorithm



# Conditional Simulation Procedure

*(Quantify Uncertainty in Risk Management Metrics)*

## Conditional Simulation

Straighten Geographic Coordinates and  
Regression on Geomorph Features

Estimate Local Cumulative Distributions  
by Indicator Natural Neighbor Interp.

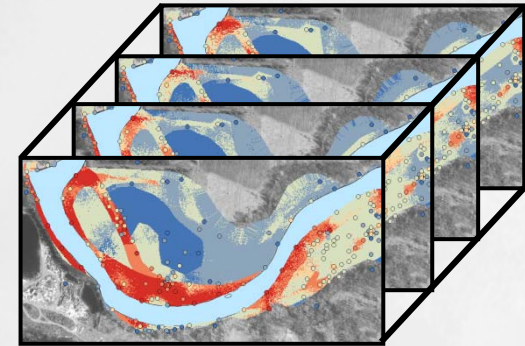
Randomly Sample Maps  
FFT based P-Field Simulation

Back Transform to PCB Scale

Implement Hill-Topping  
SWAC and Moving Home Range Analysis

Summarize as Maps and Probability  
Distributions

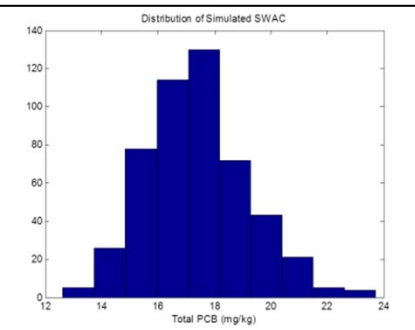
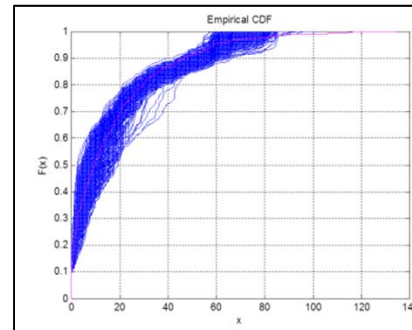
Repeat  
N=500



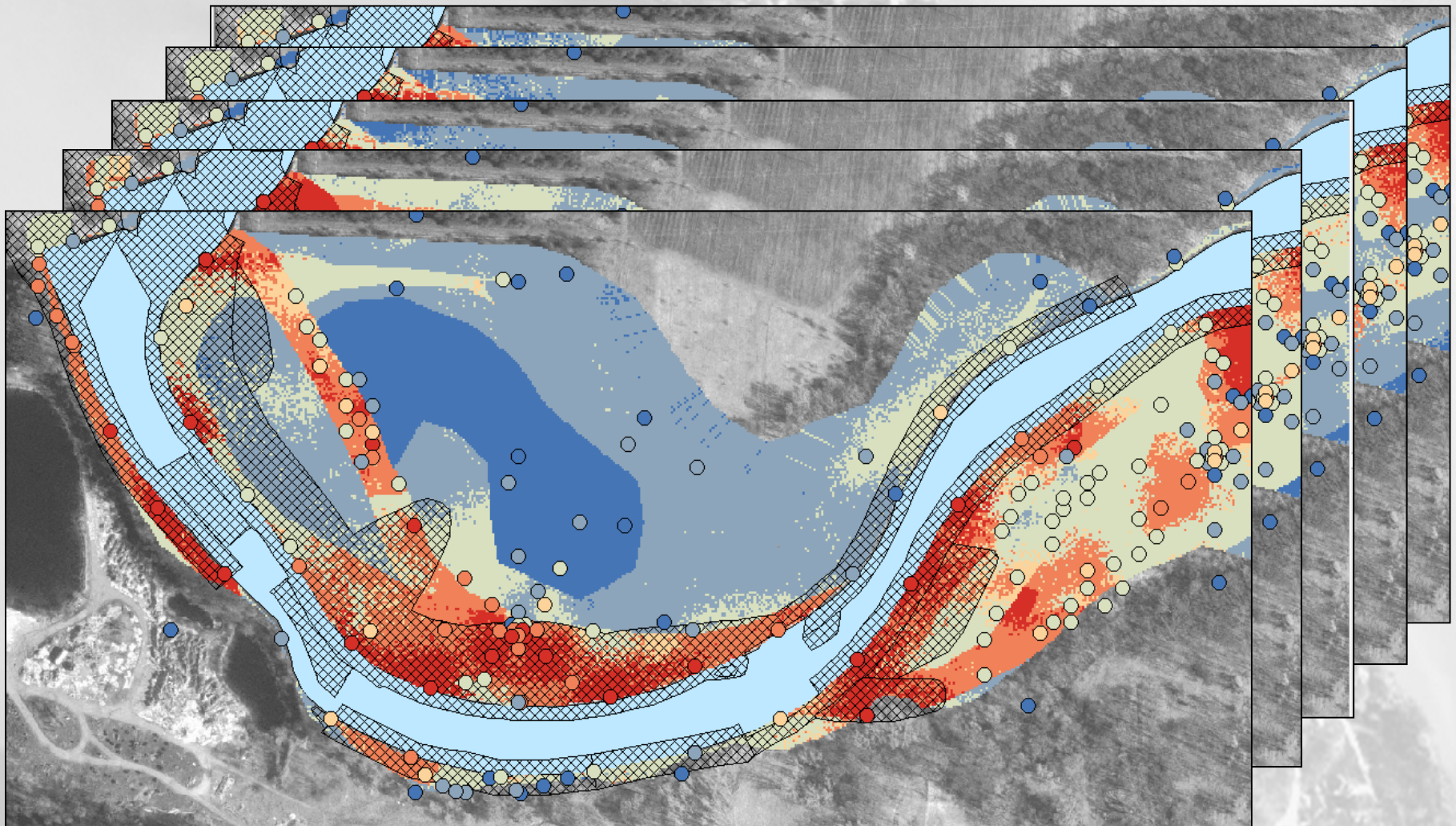
SWAC, Risk Estimates  
Percent Home Ranges  
Exceeding RBCs



## Uncertainty Distributions

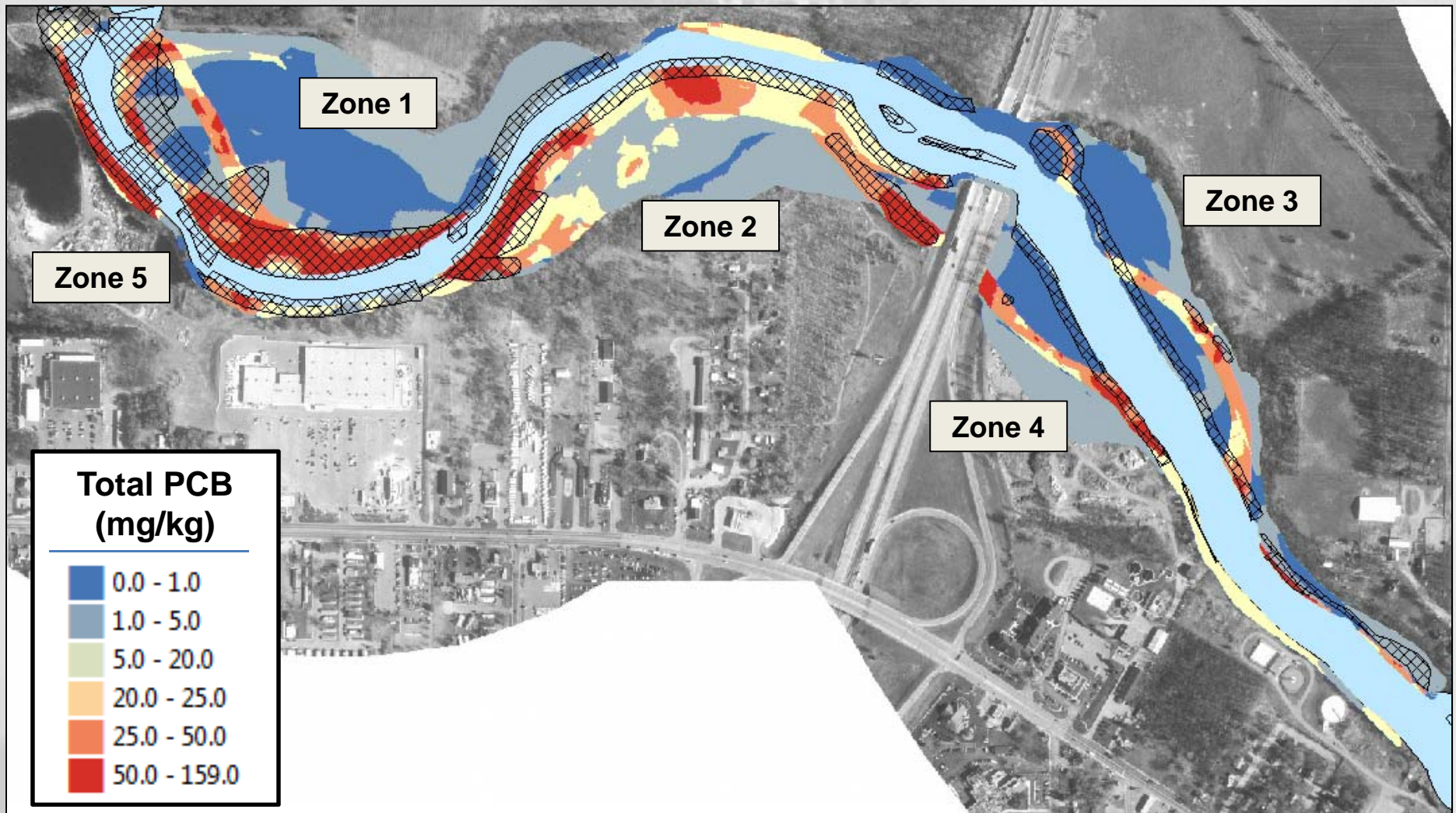


# Looking at a Few Equally Likely Surfaces is Often Informative

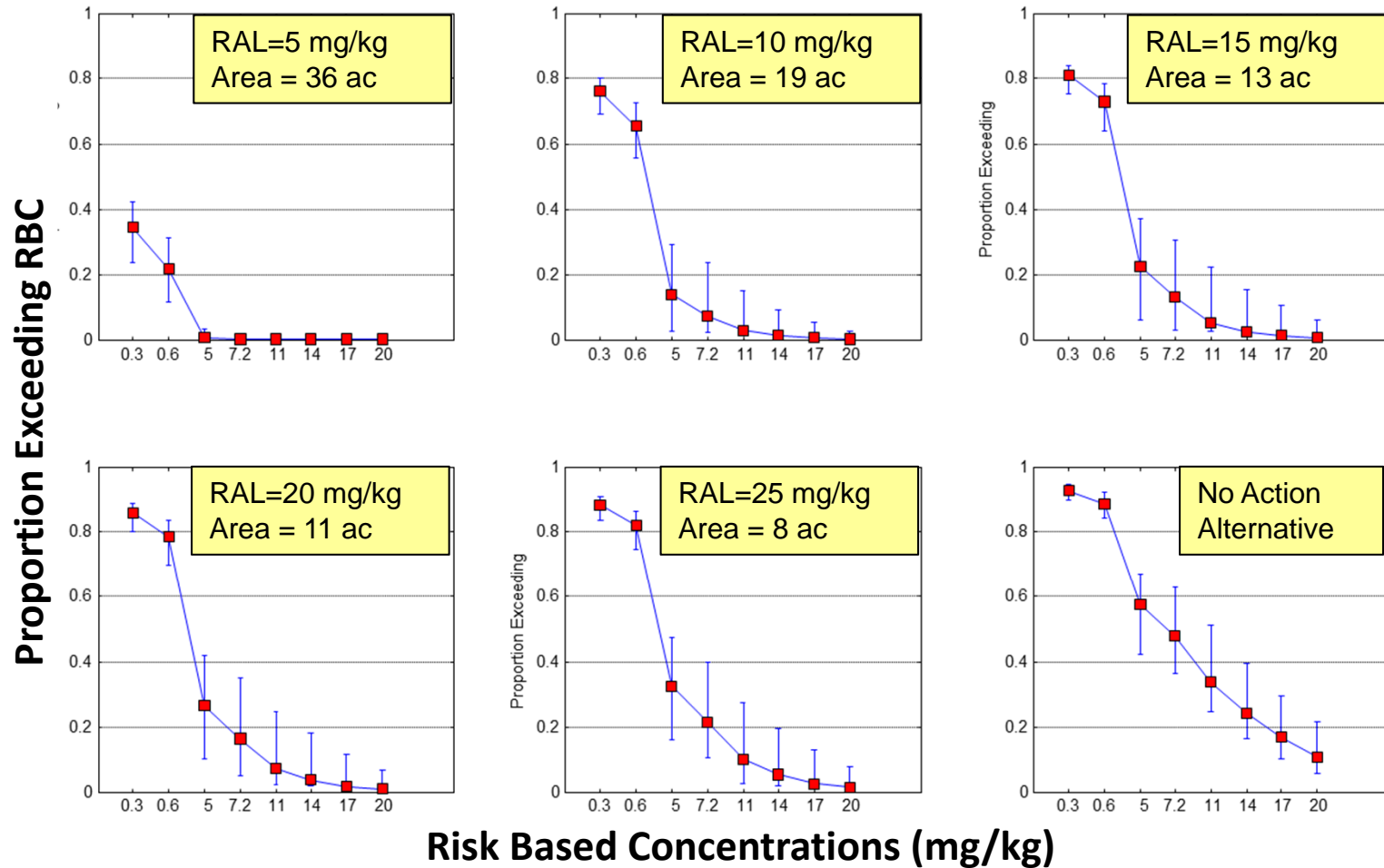


# Results

# Surface PCBs by Selected Remedial Action Limits and Geographic Zones

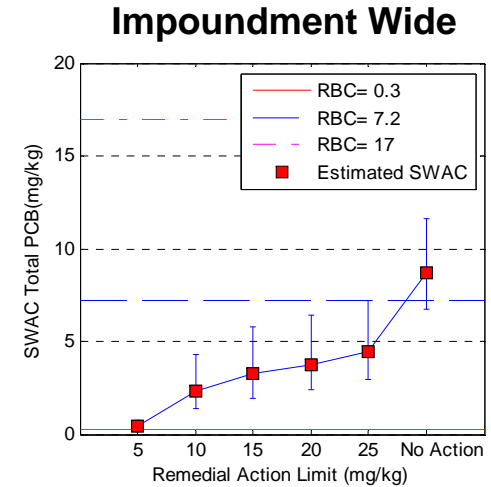
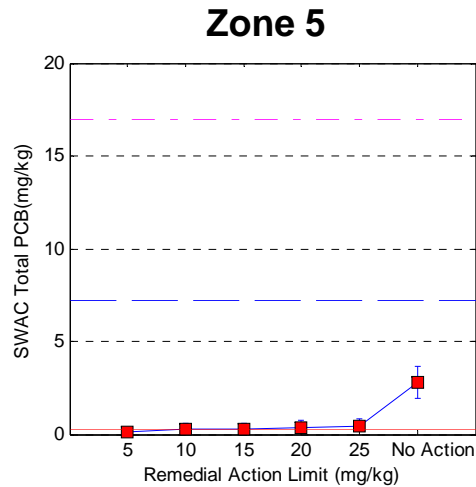
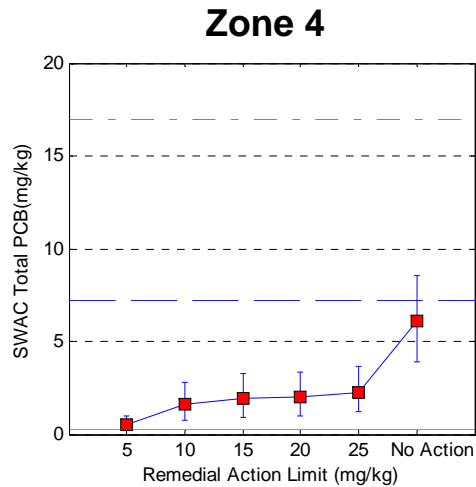
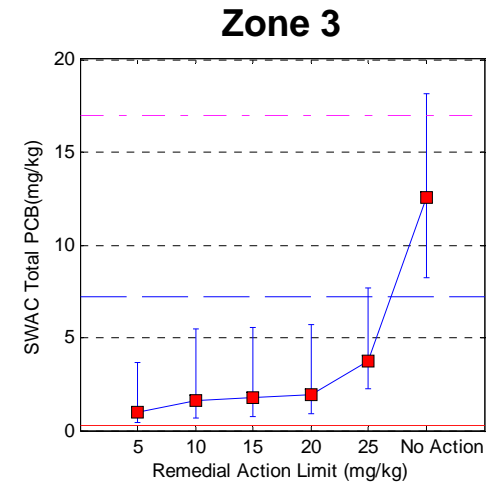
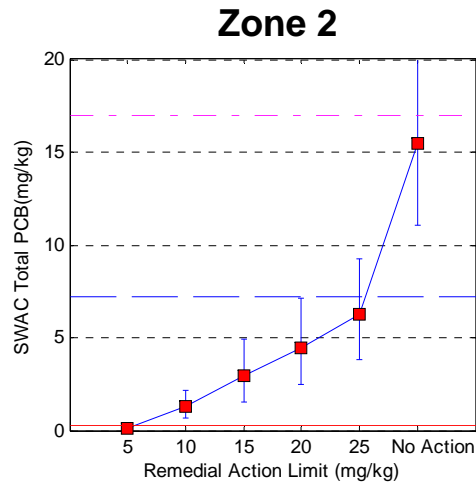
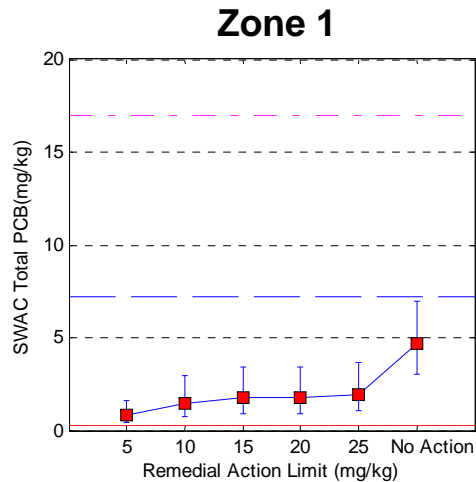


# Proportion One-acre Home Ranges Exceeding RBCs (by Remedial Action Limits)



# SWAC vs. Remedial Action Limits

## (By Impoundment Zones)



# Conclusions

- **General:**

- Inclusion of geomorphic information likely would modify remedy selection and design.
- Risk management decisions may be sensitive to uncertainty in spatial distribution of mapped quantities.
- Conditional simulation provides a powerful tool evaluate sensitivity of risk management decisions on map uncertainty.

- **Plainwell Impoundment Specific:**

- Efficiency of Time Critical Removal Action Could have been improved through incorporation of geomorphological information.
- Geostatistical analysis provided means to rigorously integrate diverse information sources.
- Conditional simulation highlighted areas that may have been removed unnecessarily.
- Effectiveness and efficiency of future remedial actions could be improved with similar analysis.